

DEVELOPMENT OF EARTH LEAKAGE CIRCUIT BREAKER WITH AN AUTO
RE-CLOSER UNIT

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Specially dedicated to my beloved family and those people who
have guided and inspired me throughout my journey of education

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ABSTRACT

Power system protection is the most important requirement before the power system is put into operation. Electrical energy has caused dangers both to the human and the machines. Protection system is mostly controlled by the Earth Leakage Circuit Breaker (ELCB). This device is the brain of the protection system that monitors input current from power line by its sensor Zero phase Current Transformer (ZCT), then sending the signals to the mechanical switch to trip the circuit breaker. ELCB is widely applied by consumer whether it is for resident, factory, laboratory and also power distribution. Power system protection can be implemented at various stages and various types of protection devices. Because industrial operation requires protection of their Equipment from the lightning, short-circuit and also over-current, so the ELCB will serve the purpose as the protection of their system. This project will attempt to improve and design the currently ELCB by using PIC microcontroller so that it has the ability to identify the fault, act accordingly, display the fault and also to re-close it back to normal. The PIC micro controller will cause the ELCB to trip when there is unbalance current from power line flow through live line and neutral line is $\geq 100\text{mA}$. In order to design it, first thing of the current from the power line need to be measure in order to monitor it using ZCT including testing the fault (over current, lightning and short circuit) and when such condition arise, it will isolate the load from power line in the shortest time possible without harming the any other electrical devices. In this project PIC microcontroller will be used to control and operate the SSR, thus replacing the current mechanical switch.

ABSTRAK

Perlindungan sistem kuasa adalah keperluan yang paling penting sebelum ia di masukkan ke dalam operasi. Tenaga Elektrik telah menyebabkan bahaya kepada manusia dan juga mesin-mesin. Sistem perlindungan biasanya di kawal oleh Pemutus Litar Bocor Kebumi (ELCB). Peralatan ini adalah otak bagi sistem perlindungan dimana ia bertindak sebagai pemerhati arus masukan daripada talian kuasa oleh pengesan Zero Pengubah Tanpa Arus Fasa (ZCT), kemudiannya ia menghantar signal tersebut ke suis mekanikal untuk terpelantikkan pemutus litar. ELCB digunakan secara menyeluruh oleh pengguna sama ada untuk kediaman, kilang, makmal dan juga pembahagian kuasa. Perlindungan system kuasa boleh digunakan di banyak peringkat oleh banyak jenis peralatan perlindungan. Oleh kerana operasi industri memerlukan perlindungan mesin mereka daripada kilat, litar pintas dan juga lebihan arus, maka ELCB ini akan digunakan bagi tujuan perlindungan kepada system mereka. Projek ini adalah cubaan bagi menambah baik dan juga mencipta semula ELCB yang sedia ada dengan menggunakan PIC pengawal mikro supaya ELCB itu nanti mempunyai keupayaan untuk mengenalpasti kesilapan, bertindak sepatutnya, menunjukkan kesilapan dan juga menyambung kembali litar ELCB yang telah terpelantik kepada asal. PIC pengawal mikro akan menyebabkan ELCB itu terpelantik sekiranya terdapat arus yang tidak stabil daripada talian kuasa yang melalui talian Life dan neutral adalah $\geq 100\text{mA}$. Bagi mencipta ELCB ini pertama sekali, arus daripada talian kuasa perlu di periksa supaya ZCT dapat memerhatikan dan termasuk memeriksa kesalahan (lebihan arus, kilat dan litar pintas) dan apabila semua criteria ini dipenuhi, ELCB tadi akan bertindak memutuskan sambungan barangan elektrik daripada talian kuasa dalam seantas mungkin tanpa merosakkan mana-mana peralatan elektrik. Dalam projek ini, PIC pengawal mikro digunakan bagi mengawal Relay keadaan tetap (SSR), yang mana telah ditukarkan daripada suis mekanikal asal.

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LIST OF ABBREVIATIONS

AC	–	Alternate Current
ADC	–	Analog to Digital Converter
DC	–	Direct Current
I_i	–	Input Current
I_o	–	Output Current
LED	–	Light Emitting Diode
LCD	–	Liquid Crystal Display
PIC	–	Programmable Intelligent Computer
SSR	–	Solid State Relay
V	–	Voltage
V_{in}	–	Input Voltage
V_o	–	Output Voltage
ZCT	–	Zero phase Current Transformer
Ω	–	Ohm

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CHAPTER 1

INTRODUCTION

1.1 Project Background

This project is focused on improving the current ELCB that is using mechanical switch into a new ELCB that using electronic switch. Nowadays ELCB is manually controlled by mechanical switch and have a limited function which are cannot distinguished and notify either permanent or temporary fault that occurred. The problem comes when there is no resident at house whenever the fault or tripping occurred. The electrical equipment power will be disconnected will cause some trouble for the resident. We can take an example if there is no resident currently in the house for a while and the ELCB in the resident is currently trip, some Electrical equipment like refrigerator and water pump for aquarium will become malfunction. Thus the fresh vegetable and meat in the fridge will expired and smelly meanwhile the fish in the aquarium may die because lack of oxygen. This may seems unimportant, but if we can solve this problem we can make human life a bit easier. As a future engineer who is a problem solver, we need to solve this problem as our first task. The focus of this project is to design and improving the current ELCB to a new ELCB with an auto re-closer unit. The new ELCB function does not limited at the auto switching, but it also can differentiate and display the type of fault so that the user is aware of the situation.

There are two types of fault normally detected by ELCB, which are permanent fault and temporary fault. Permanent fault is type of fault that occurred because of short-circuits between both live wire and neutral wire or ground wire, meanwhile temporary fault is type of fault that occurred from the effect of surge current from the lightning. The basic concept of the ELCB is if there are fault occurred, ZCT will sense the fault and send the signal to the ELCB to cut the power to the load (tripped). After 10 second the ELCB will connect back the power to the load, after that if the ELCB is remain connected with the load that means the fault is temporary like lightning. Meanwhile if after the ELCB is connected back to the load and it still detect any fault, it will re-close back. The cycle will be repeated for 3 times, if the fault is still detected, the ELCB will isolated the power from the load and it will display the fault is permanent like short-circuit or over-current. Until the fault is correct by the user, the ELCB will remain tripped and the user need to manually switch on the ELCB after the fault is correct to avoid electrical hazard. In this project the PIC microcontroller has been chosen as a control element, and the Solid State Relay (SSR) is selected as switching device.

The first problem we need to be clear in this project is to understand and know the differentiation between permanent fault and temporary fault. All aspect must be considered and we cannot neglect even a little for the safety of human life. The second problem is how to convert mechanical switch from original ELCB to a new electronic ELCB. Original ELCB used the principal of magnetic, and we need to change the signal of magnetic to electrical signal for the new ELCB. The third problem need to be clear is sensing element that can be use to send the fault signal to the PIC. For all this to operate together, we need to choose suitable components with rating current and voltage that is suitable to operate together and then start designing the suitable circuit that connect all the system.

1.2 Objectives:

The objectives of this project are:

- i. To design an ELCB with an auto re-closer unit.
- ii. To implement the use of Micro-C and power electronic switch in designing hardware.
- iii. To notify user either the fault mode is temporary or permanents.

1.3 Scope of project

- i. To improve the currently Earth Leakage Circuit Breaker (ELCB) into a new ELCB which have the ability to automatically trigger on back after being trip.
- ii. The new ELCB can also distinguish either it is permanent fault or temporary fault that occur and it will only trigger on when necessary.
- iii. To ensure this project work perfectly, the use of PIC18F4550 and P-Spice software will be implement.

1.4 Literature Review

An Earth Leakage Circuit Breaker (ELCB) is a device with two earth terminals used to directly detect currents leaking to earth from an installation and cut the power. They were mainly used on TT earthing systems. By having the assumption of the presence of current in the earth line, it means there is any leaking current from the main incoming live cable, thus the power has to be cut off to ensure the safety. The state of the ELCB when it cuts the power is known as being tripped. Every time the ELCB is tripped, it can be reset (connected back the power line) by resetting the trip button. Originally there are two types of ELCBs, the voltage operated device and the differential current operated device vELCB and iELCB. vELCBs were first introduced about sixty years ago and iELCB were first introduced about forty years ago [3].

The principle of operation of the vELCB is as follows. Under normal conditions the closed contacts of the vELCB feed the supply current to the load. The load is protected by a metal frame, such as in an electric cooker. The vELCB also has a relay coil, one end of which is connected to the metal frame and one end connected directly to ground. A shock risk will arise if a breakdown in the insulation occurs in the load which causes the metal frame to rise to a voltage above earth. A resultant current will flow from the metalwork through the relay coil to earth and when the frame voltage reaches a dangerous level, e.g. 50 volts, the current flowing through the relay coil will be sufficient to activate the relay thereby causing opening of the supply contacts and removal of the shock risk [3].

ELCB is essentially a voltage sensing device intended to detect dangerous voltage and current fault. The level of shock protection provided by the vELCB was somewhat limited as these devices would not provide shock protection in the event of direct contact with a live part. An additional problem with the vELCB was its tendency to be tripped by earth currents originating in other installations [3].

For many years, the voltage operated ELCB and the differential current operated ELCB were both referred to as ELCBs because it was a simpler name to remember. However, the use of a common name for two different devices gave rise to considerable confusion in the electrical industry. If the wrong type was used on an installation, the level of protection given could be substantially less than that intended. To remove this confusion, IEC decided to apply the term Residual Current Device (RCD) to differential current operated ELCBs. Residual current refers to any current over and above the load current.

Through early research that have been done and the guidelines from articles, it states that the development of ELCB is focused to only development of better device and not to improve the system of ELCB cause there are no articles that give the idea how to add the function and system to this ELCB. Until today what the article said is the type, function and process of each component in ELCB. So it is important to struggle and combine all knowledge to design something new for this device [4].

1.5 Thesis Outline

This thesis contains 5 chapters which is every chapter have its own purpose. After viewing the entire chapter in this thesis, hopefully the viewer can understand the whole system design for this project.

Chapter 1 describe on the background of the project, objectives, scope of the project and the literature review that referred to in the development of Earth Leakage Circuit Breaker with an auto re-closer unit.

Chapter 2 is focused to the theory of the Earth Leakage Circuit Breaker (ELCB), where it described about problems, ELCB design, the components inside ELCB and the operation of this device.

Chapter 3 elaborated more on the designing and operation of the new ELCB with an auto re-closer unit system. Besides it also describe the functions of each components used in the circuit especially on the second stage circuit.

Chapter 4 is focused to the control element circuit which is the most important part of the system. It described about the system of microcontroller detailed from the hardware until the software that has been used in this project.

Chapter 5 presents the data and experimental result while in development process. The result of this project is also accompanied by the discussions for each problem statements.

Lastly is Chapter 6, in this chapter the conclusion have been made for the project from the whole aspect and there are also suggestions to improve the new ELCB in the future, in case for the commercialization. The costing stated to produce the ELCB is also included.

CHAPTER 2

EARTH LEAKAGE CIRCUIT BREAKER

2.1 Introduction

An Earth Leakage Circuit Breaker (ELCB) is a device used to directly detect currents leaking to earth from an installation and cut the power. Early ELCBs responded to sine wave fault currents, but not to rectified fault current. Over time, filtering against nuisance trips has also improved. Early ELCBs thus offer a little less safety and higher risk of nuisance trip. The ability to distinguish between a fault condition and non-risk conditions is called discrimination. Many electrical installations have relatively high earth impedance. This may be due to the use of a local earth rod (TT systems), or to dry local ground conditions.

This type of installation is dangerous and a safety risk if a live to earth fault current flows. Because of earth impedance is high:

- i. Not enough current exists to trip a fuse or circuit breaker, so the condition persists unclear indefinitely.
- ii. The high impedance earth cannot keep the voltage of all exposed metal to a safe voltage, all such metalwork may rise to close to live conductor voltage.

These dangers can be drastically reduced by the use of an ELCB or Residual-current device (RCD).

The ELCB makes such installations much safer by cutting the power if these dangerous conditions occur. This approach to electrical safety is called EEBAD. In Britain EEBAD domestic installations became standard in the 1950s.

In non-technical terms if a person touches something, typically a metal part on faulty electrical equipment, which is at a significant voltage relative to the earth, electrical current will flow through him/her to the earth. The current that flows is too small to trip an electrical fuse which could disconnect the electricity supply, but can be enough to kill. An ELCB detects even a small current (ZCT sensitivity) to earth (Earth Leakage) and disconnects the equipment (Circuit Breaker).

This chapter describe about detail of ELCB and about its operation so that the reader will get a clear idea how the ELCB is working. To achieve that first we need to study more about ELCB and doing some research about the ELCB operation

The objectives of this chapter are:

- i. To know the system of basic Earth Leakage Circuit Breaker
- ii. To know the components of Earth Leakage Circuit Breaker and know the function of each component.
- iii. To understand how the device work

2.2 Problems of nowadays ELCB

Earth Leakage Circuit Breaker is one type of electrical equipment that used as a protection device. The main purpose of this type of equipment is to cut off the power when the problem occurred. But the problem is will the device back to normally condition and function if the error occurred and there are no a human that can switch on back the device due to many reasons.

The device is using mechanical switch that must be switch on manually, after ELCB is being tripped it will stay off until the user push it back to the on condition although the problem that occurred is temporary fault and occurred in one millisecond.

The device also can not differentiate whether the fault is temporary or permanent fault where there are the differentiations between these two types. It also does not act differently for these two types of faulty.

2.3 Electrical faults

A fault is any abnormal situation in an electrical system in which the electrical current may or may not flow through the intended parts. Equipment failure also attributable to some defect in the circuit, example is loose connection, insulation failure or short circuit etc. The ype of faults in a distribution network that is detected by an ELCB is:

- i) Over-Current Fault
- ii) Short-Circuit Fault
- iii) Lightning Fault